THE EFFECT OF LIFT HEIGHT ON MAXIMAL LIFTING CAPABILITIES OF MEN AND WOMEN

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The purpose of this study was to determine the effect of lift height on the one repetition maximum box lifting strength (1 RM) of men and women. Ten men and eleven women lifted to heights of 1, 2, 3, 4, 5, and 6 ft using a 46.5 cm long x 31 cm wide x 23 cm high aluminum box with handles. All lifts were accomplished using correct lifting technique while facing forward. An ANOVA, focused on six heights and blocked for gender was used for analysis. A Newman-Kuels post-hoc analysis was used to examine the significant differences between means. Results revealed that men lifted more than women overall ($F = 128.9$, $p < 0.01$), and at each individual height ($p < 0.01$). When the genders were combined, the two highest lifts (5 and 6 ft) were not different from each other, nor were the two lowest (1 and 2 ft). All other heights differed from one another ($p < 0.01$). For both genders, the greatest percentage decrease from one height to the next occurred between 3 and 4 feet, when more upper body strength and torso involvement were required.

INTRODUCTION

Knowledge of maximal lifting capacities is important when a reduction in object mass is not possible, mechanical aids can not be used, or in an emergency situation which requires immediate individual action. Such information is also necessary to estimate the percentage of soldiers entering the Army who may potentially qualify for a given military occupational specialty requiring heavy lifting and to estimate manpower needs during conflict. In addition, these data guide contractors in the design and packaging of equipment.

Military and civilian manual material handling tasks require men and women to lift loads to various heights. Prior lifting research has primarily focused on identifying acceptable lifting limits to reduce risks to the musculoskeletal system, as opposed to identifying maximal lifting capabilities. In addition, evaluations of the effect of lift heights on lifting capabilities have used relative heights based on the individual volunteer's anthropometric dimensions, rather than absolute heights (Snook and Ciriello, 1991).

Although Emanuel, Chaffee, and Wing (1956) identified maximal lifting capabilities from the floor to a five foot level (in one foot increments) for men, these capabilities have not been identified for women. Emanuel and his co-investigators had subjects stand beside a custom built staircase, face the rear of the staircase, lift an F-86H Ammunition case, place the end of the case on the designated step and slide it sideways onto the platform. As a result, it appears the lifts required some twisting motion. The objective of the present study was to quantify maximum lifting capabilities of men and women to various heights using correct lifting technique and facing forward.

METHODS

Participants included 10 male and 11 female active duty soldiers. All subjects were medically screened and signed an informed consent form

Table 1. Physical characteristics of subjects.

	Men (mean ± SD)	Women (mean ± SD)	Percent Difference
n	10	11	
age (yr)	21.4 ± 3.5	22.0 ± 4.7	
height (cm)	178.1 ± 4.7	162.1 ± 4.0*	
weight (kg)	81.6 ± 7.1	59.3 ± 7.5*	
body fat (%)	17.8 ± 5.4	27.6 ± 5.8*	
fat-free mass (kg)	66.3 ± 4.3	42.2 ± 3.8*	
dead lift (kg)	132.5 ± 20.5	64.4 ± 17.2*	49%
38cm uprt pull (kg)	153.4 ± 28.6	84.4 ± 8.0*	55%
bench press (kg)	92.3 ± 19.9	33.4 ± 5.0*	36%
hand grip (kg)	56.8 ± 8.1	29.2 ± 3.8*	51%
IDL (kg)	75.6 ± 8.5	42.5 ± 12.3*	56%

* Significantly different from men ($p < 0.01$).

following a detailed briefing. The body composition of volunteers was determined by dual energy x-ray absorptiometry (Mazess, Barden, Bisek, and Hanson, 1990). The maximal strength measures included a dead lift, 38 cm upright pull (uprt pull), incremental dynamic lift (IDL) (Sharp, Rice, Nindl, and Williamson, 1993), dynamic bench press, and isometric hand grip. Table 1 contains the physical characteristics and strength measures of the subjects. The women were shorter, lighter, had a higher percent body fat, and lower quantity of fat free mass than men ($p < 0.01$). Women's strength capabilities were lower than men's on all measures ($p < 0.01$).

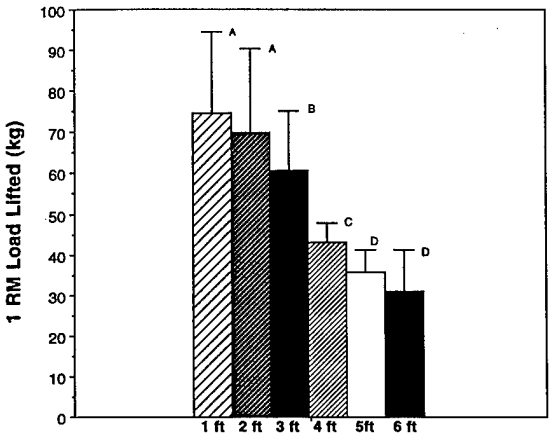
All box lifts were performed using an adjustable shelf, which allowed subjects to face forward when lifting (Teves, McGrath, Knapik, and Legg, 1986). A 6.1 kg aluminum box with handles was used. The box was 46.5 cm long x 31 cm wide x 23 cm high. The warm-up consisted of one set of three lifts at 30% or less of the volunteer's predicted 1 repetition maximum (1 RM), followed by a second set of three lifts at less than 50% of their predicted 1 RM (Semenick, 1994). Weight was added according to each volunteer's subjective assessment of his or her ability and was generally in 1-10 kg increments. After a failed attempt, weight was removed to yield an intermediate load to assess 1 RM as accurately as possible (to the nearest 1.0 kg). Maximum load was reached when the subject judged the weight as too heavy, could not physically complete the lift, or could not maintain a safe lifting technique. A minimum of three minutes rest was given after each attempt. The investigator monitored the weight added so that proper procedures and appropriate increments were used.

Volunteers lifted the box from the floor to heights of 1 to 6 feet, in one foot increments. No more than two lifts were performed in one day. If two lifts were performed during the same day, a minimum of 3 hours rest was given between lifts.

An ANOVA, focused on six heights and blocked for gender was performed. A Newman-Kuels post-hoc analysis examined the significant differences between means. An independent t-test was used to determine differences in strength and anthropometric measures between men and women.

RESULTS

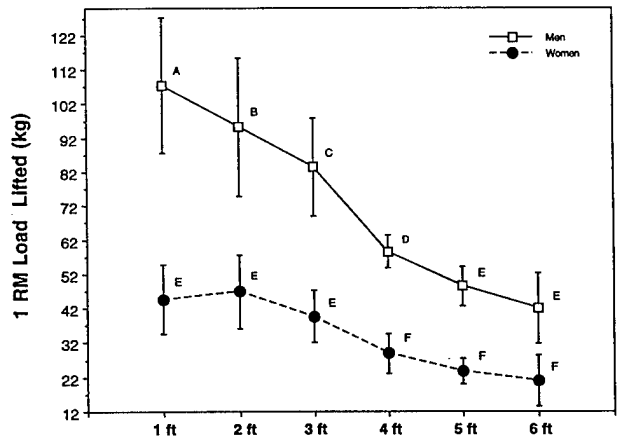
A significant height effect was observed ($F = 93.2$, $p < 0.01$). Figure 1 shows the loads lifted to each height by men and women. Loads lifted to the lowest two heights (1 and 2 ft) and loads lifted to the two highest heights (5 and 6 ft) were not significantly different from each other ($p > 0.05$). All other heights were significantly different from each other ($p < 0.01$).



Bars with different heights are different from each other ($p < 0.01$).

Figure 1. Main Effect for Height

Overall, men lifted more than women (men = 72.5 kg, women = 34.2 kg, $F = 128.9$, $p < 0.01$), and they lifted more than women at each height ($p < 0.01$). Figure 2 shows a significant gender x height interaction ($F = 17.2$, $p < 0.01$).



Different letters indicate significant differences ($p < 0.01$)

Figure 2. Height by Gender Interaction.

Men showed a steady decline in load lifted with an increase in lifting height with the exception of lift heights 5 and 6 feet. Women did not demonstrate this same pattern. Instead, they lifted similar loads for lift heights 1 to 3 feet and a lower load to lift heights 4 to 6 feet, with no steady decline across lift heights. The load lifted by women at heights up to 3 feet was not significantly different from that lifted by men to 5 or 6 feet.

Table 1 shows the female-to-male percent differences (women/men*100) for descriptive strength measures. The female-to-male percent differences for each 1 - 6 foot lift were 42%, 49%, 48%, 49%, 49%, and 50% respectively. That is, at a height of 1 foot, women lifted 42% of the load that men lifted. Table 2 shows the percent decrease ((higher lift-lower lift/lower lift)*100) in weight lifted with each increment in height for men and women. Except for the 1 foot height, the percent decrease at each height was similar for men and women. The greatest percent decrease occurred between the 3 and 4 foot lifts for both genders (men = 29.7%, women = 27.1%).

Table 2. Percent change in lift with each increase in height.

Height	Combined Gender	Men	Women
1-2 ft	- 6.2	-11.4	+ 5.0
2-3 ft	-13.4	-12.4	-15.3
3-4 ft	-28.8	-29.7	-27.1
4-5 ft	-17.3	-17.3	-17.3
5-6 ft	-12.9	-13.4	-12.1

Another perspective for evaluating the effect of lift height is to examine the percent difference in load lifted to the lowest height with the load lifted at each of the higher heights. When the genders were combined, the greatest load was lifted to the height of 1 foot. At 2 feet, volunteers lifted 6.2% less than they lifted to 1 foot. When lifting to 3 feet, volunteers lifted 18.8% less than they lifted to 1 foot. At 4 feet, they lifted 42.2% less, at 5 feet -

52.2% less, and at 6 feet - 58.4% less than the load they lifted to 1 foot.

DISCUSSION

This study demonstrated the maximal capabilities of men and women lifting to heights of 1, 2, 3, 4, 5, and 6 feet. When both genders were combined, no differences were seen between loads lifted to the two lowest heights (1 and 2 feet) or to the two highest heights (5 and 6 feet). This indicates that when designing tasks, weight limits for these heights could be combined. It is suggested that the lower limit capabilities be used, ie. the 2 foot load for the lower height and the 6 foot load for the higher height.

Men lifted more than women at each height. Previous studies that involved maximal box lifts from the floor to shoulder height demonstrated that women were able to lift 60% that of men (Beckett and Hodgdon, 1987; Myers, Gebhardt, Crump, et al., 1984; Teves, Wright, and Vogel, 1985). This is considerably more than the strength differences for box lifts (42-50%) seen in this study. The isometric strength of female soldiers has been reported to be more comparable to male soldiers for lower-body strength (67%) than for upper-body strength (60%)(Knapik, Wright, Kowal, et al., 1980; Sharp, 1994). These female-to-male percentages are greater than those found in this study (lower body 49-55% and upper body 36-51%). It appears the upper-body strength was less for women and slightly greater for men in this study than seen in previous studies. Because of these issues, we might expect the gender difference in weight lifted to be exaggerated at higher lift heights. However the percent differences were approximately the same (42-50%) throughout the range of heights.

The greatest difference in both absolute weight lifted and percentage of weight change between each height occurred between the 3 and 4 foot heights for both men and women. Men lifted progressively less as the height increased, except for the final two heights of 5 and 6 feet. Women on the other hand, lifted similar weights to 1, 2, and 3 foot heights, and to 4, 5, and 6 foot heights. However, the percent change for each height was similar for men and women. The greatest change in upper body strength requirements, torso involvement, and upper extremity biomechanics occurs between 3 and 4 foot lifting heights.

Table 3 shows the maximum weight lifted to each height for male subjects from this study and for the research conducted by Emanuel, et al. (1956). The results were similar at the two lower heights; however, our subjects lifted more at the 3 - 5 foot heights. This may be the result of the method of lifting, placing, and sliding the box onto the shelf in the study by Emanuel, et al. (1956). Although these authors state that their subjects held their backs straight and faced straight ahead, it would be necessary to turn one's head slightly to see the stair on which they were to place the box. Even this slight movement could involve some twisting of their torso and have influenced their maximum loads. In addition, the box size and configuration differed from ours. They used an F-86H aluminum ammunition case 64.8 cm long x 32.8 cm wide (box height was not noted), with handles. The longer box may have required the volunteers to adduct their shoulders and extend their elbows, thus putting their upper extremities at a greater biomechanical disadvantage during higher lifts.

Table 3. Comparison of maximum lifting capabilities (kg) of men from this study compared with Emanuel, Chaffee, and Wing, 1956.

Height	Present study (mean ± SD)	Emanuel, et al. (mean ± SD)
1 ft	107.4 ± 19.9	104.9 ± 21.3
2 ft	95.2 ± 20.3	87.6 ± 18.2
3 ft	83.4 ± 14.5	54.0 ± 14.1
4 ft	58.6 ± 4.8	36.8 ± 8.6
5 ft	48.5 ± 5.7	26.3 ± 7.3
6 ft	42.0 ± 10.2	not tested

CONCLUSION

Maximal lifting capabilities for men and women at heights of 1, 2, 3, 4, 5, and 6 feet were identified in this study. The maximal lifting capabilities for men exceeded those reported previously (Emanuel, et al., 1956). Since there were no significant differences in the load lifted at the two lowest heights and the two highest heights when genders were combined, it is possible that the weight limits for these heights could be combined (based on the lower value for each). The results further demonstrate that the greatest changes in individual lifting ability occur as the lift approaches and exceeds waist height.

The views, opinions and/or findings contained in this article are those of the author and should not be construed as an official Department of the Army position, policy, or decision. The investigators adhered to the policies regarding the protection of human subjects as prescribed by 45 CFR 46 and 32 CFR 219 (Protection of Human Subjects).

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